Structural Support and Cooling of the Intermediate Silicon Layer at CDF

Giobatta Lanfranco

Fermilab
PPD/ Mechanical Department

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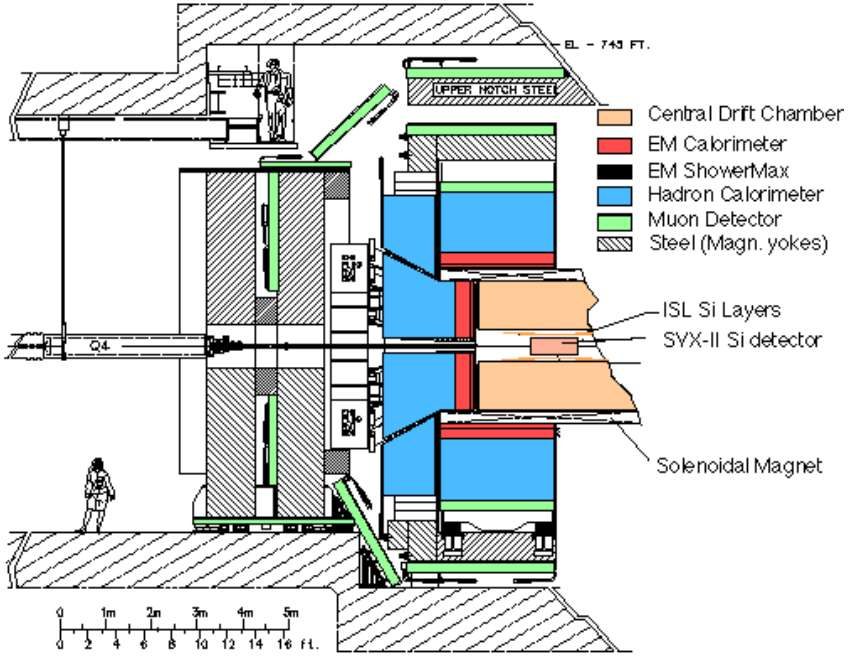
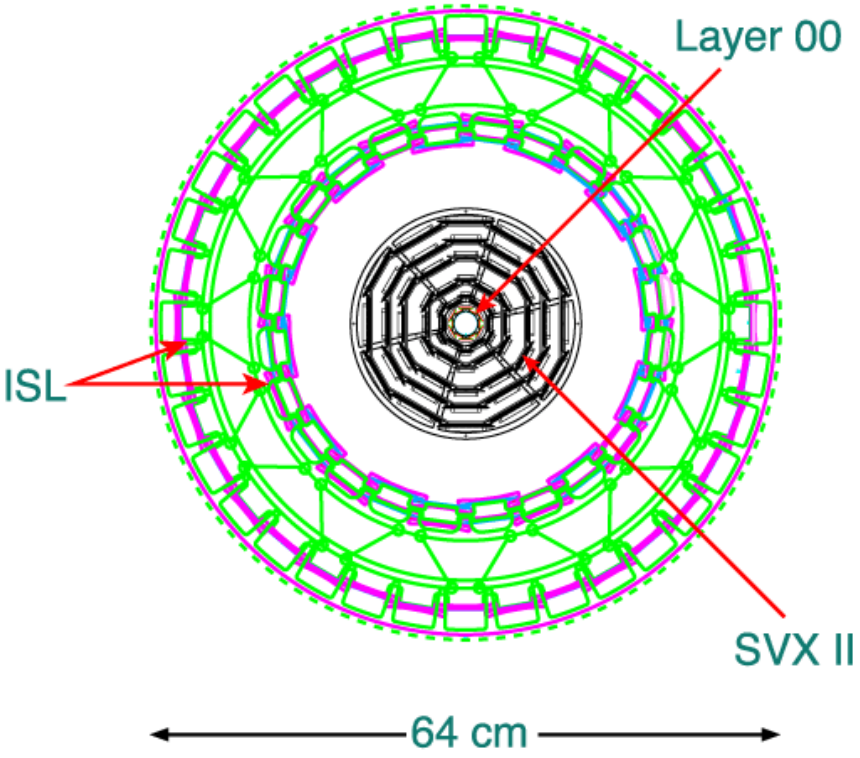
Outline

- What is the ISL space frame?
- The space frame construction
- The ISL cooling
- Conclusions



What is the ISL Space Frame?

- The Space Frame is the supporting structure of the ISL detector
- It provides supports to
  - The silicon ladders
  - The read-out electronics
  - The cooling system
- ISL & SVXII combined provide a precision standalone silicon tracking system with up to 7 axial and 7 stereo measurements

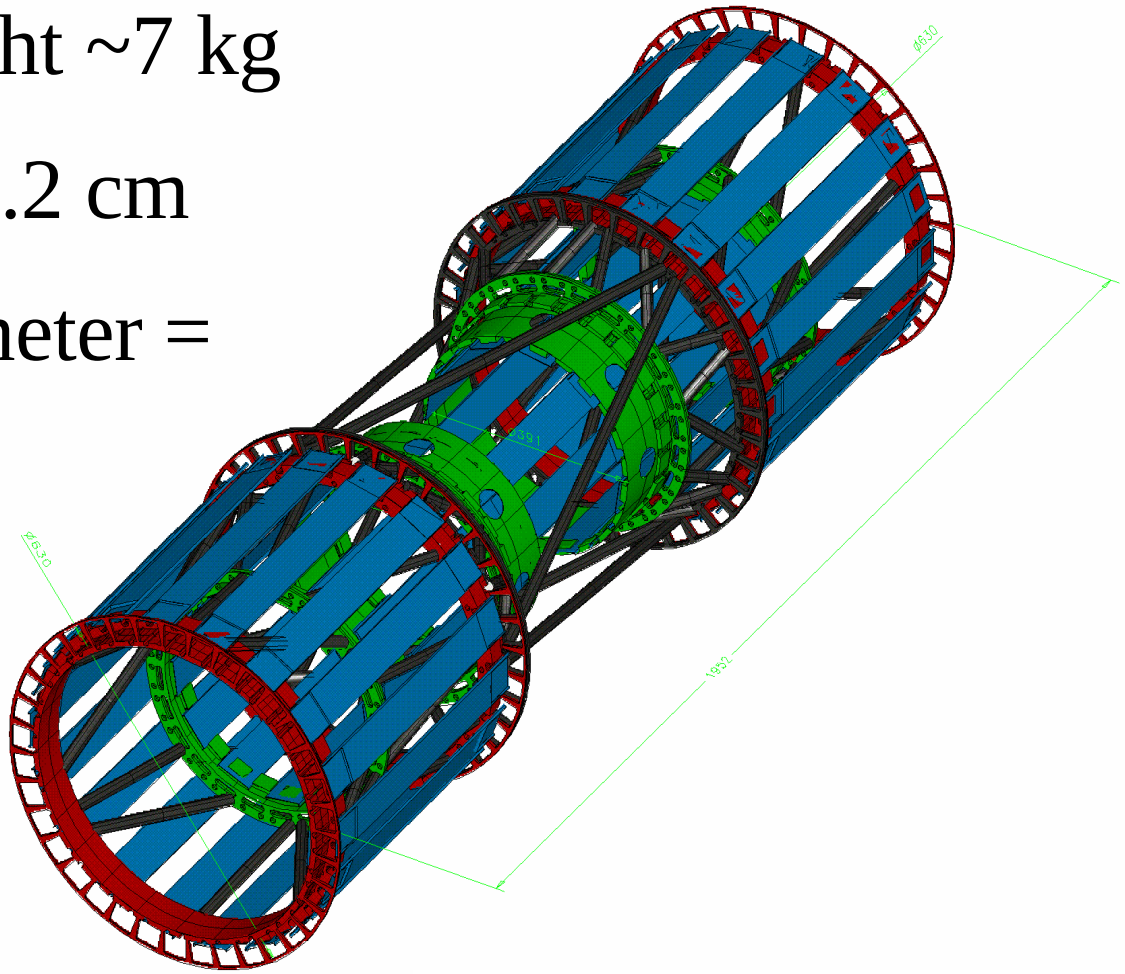


Requirements

- Accuracy in modules location and detectors alignment stability
- Low material budget
- Efficient cooling system
- Accessibility (maintenance)

Space Frame Mechanical Design

- Total Weight ~7 kg
- Length 195.2 cm
- Outer Diameter = ~64 cm



Note: (Every second ladder displayed)

ISL geometrical specs

Silicon Detector sizes:
Layer 7F & 7B Micron Semiconductors

Pich size R ϕ 112 micron
Pich size R Z 112 micron

Number of chips on R ϕ side 4
Number of chips on R Z side 4

Number of channels on R ϕ side 512
Number of channels on R Z side 512

Physical size: Width - 39.280 mm
Length - 74.772 mm
Thickness - .3 mm

Active size: Width - 57.560 mm
Length - 72.632 mm

Silicon Detector sizes:
Layer 6F & 6B and 6C Hammamatsu.

Pich size R ϕ 112 micron
Pich size R Z 112 micron

Number of chips on R ϕ side 4
Number of chips on R Z side 4

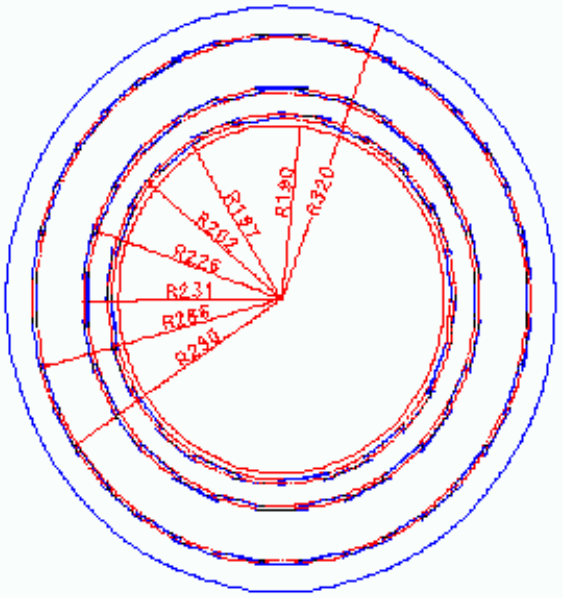
Number of channels on R ϕ side 512
Number of channels on R Z side 512

Physical size: Width - 39.280 mm
Length - 99.020 mm
Thickness - .3 mm

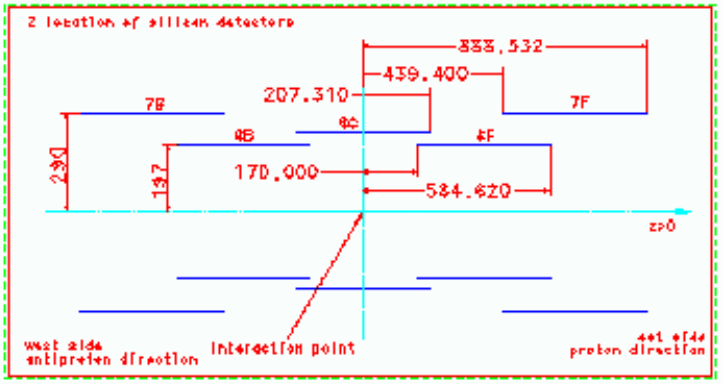
Active size: Width - 57.560 mm
Length - 97.500 mm

Layer Name	rR min (mm)	rR max (mm)	Number of ladders	z Z min (mm)	z Z max (mm)	ACC. RϕS (±)	ACC.RZ (±)
6 C	226	231	28	-207.310	207.310	111.756	
6 F	197	202	24	170.000	584.620	109.547	
6 B	197	202	24	-584.620	-170.000	109.547	
7 F	286	290	36	439.400	888.532	114.140	
7 B	286	290	36	-888.532	-439.400	114.140	

± Radius in table are referred to the R ϕ surface.
± The Z position are referred to the physical size of the detector.



Radial location of silicon detectors.



Dimension limits: Inner radius = 190 mm
Outer radius = 320 mm
Z Max = 983 mm
Z Min = -983 mm

The Space Frame Components Layups

FLANGES

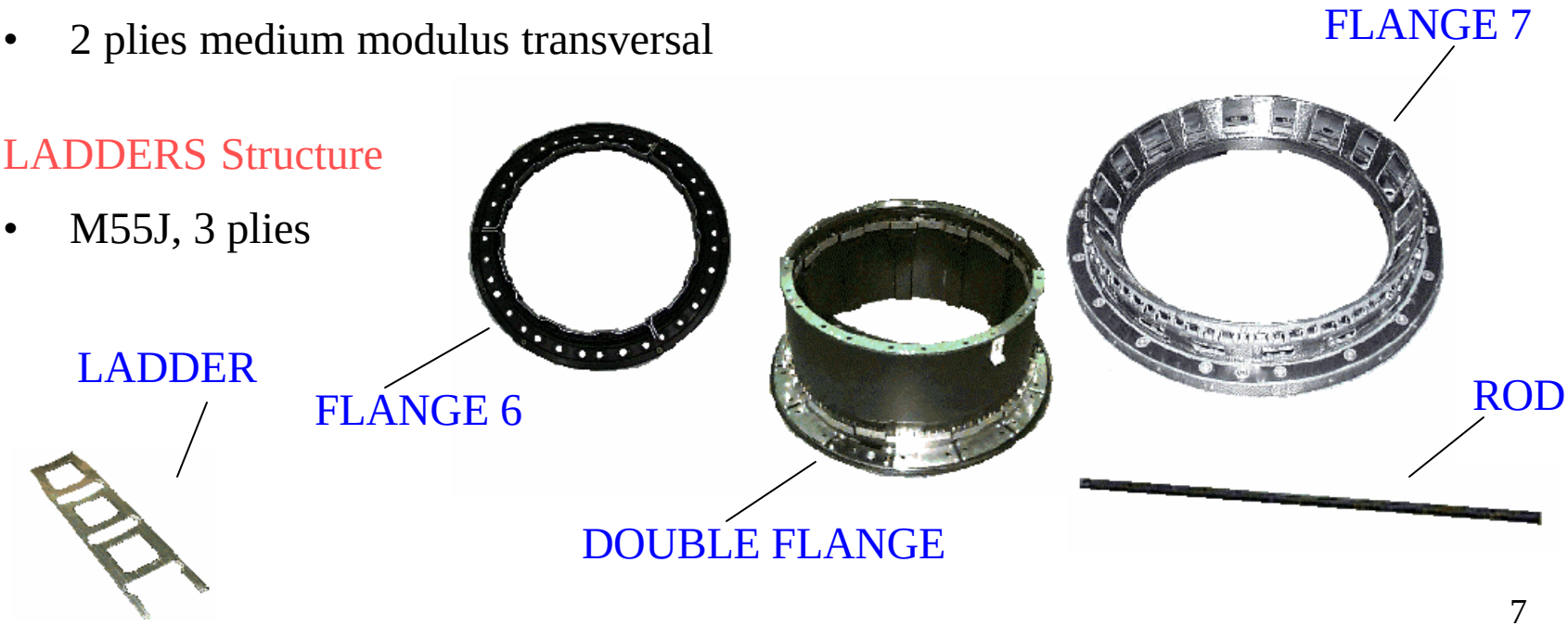
- Large Surfaces: unidirectional prepreg, 4 plies ~400micron thick
- Complex shapes: carbon fiber fabric M40, 2 plies

RODS

- 4 plies high modulus prepreg
- 2 plies medium modulus transversal

LADDERS Structure

- M55J, 3 plies

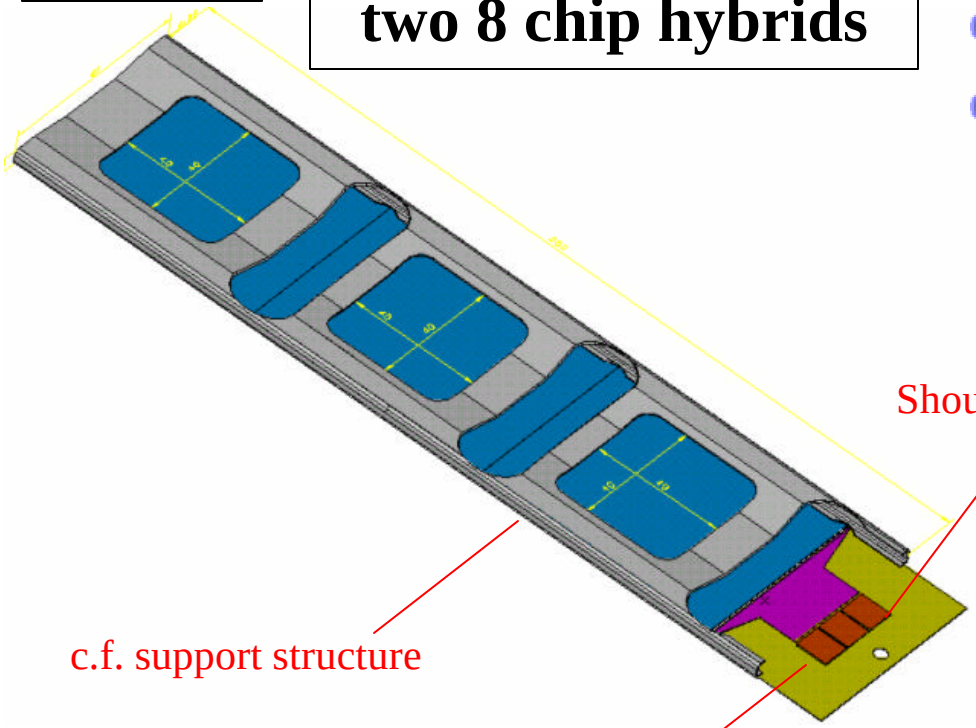


The ISL Ladder

- Full rigidity reached with sensor gluing
- Total pin to pin distance ~500mm
- max rigidity & min material due to carbon fiber design
- Sensor flatness < 15microns
- Geometry allows easy microbonding

six silicon detectors
+
two 8 chip hybrids

Stereo side

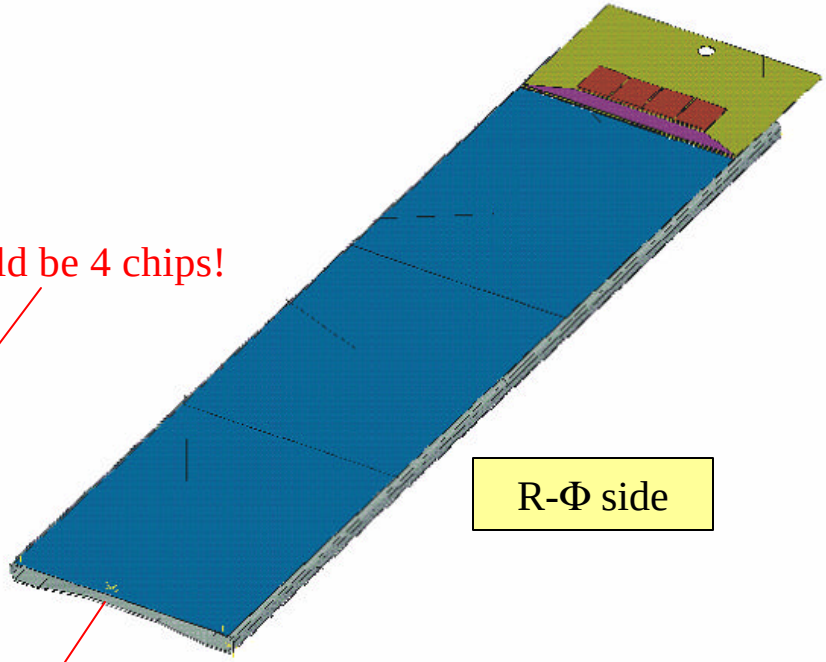


c.f. support structure

SVX-3 chips

650 mW each

Should be 4 chips!

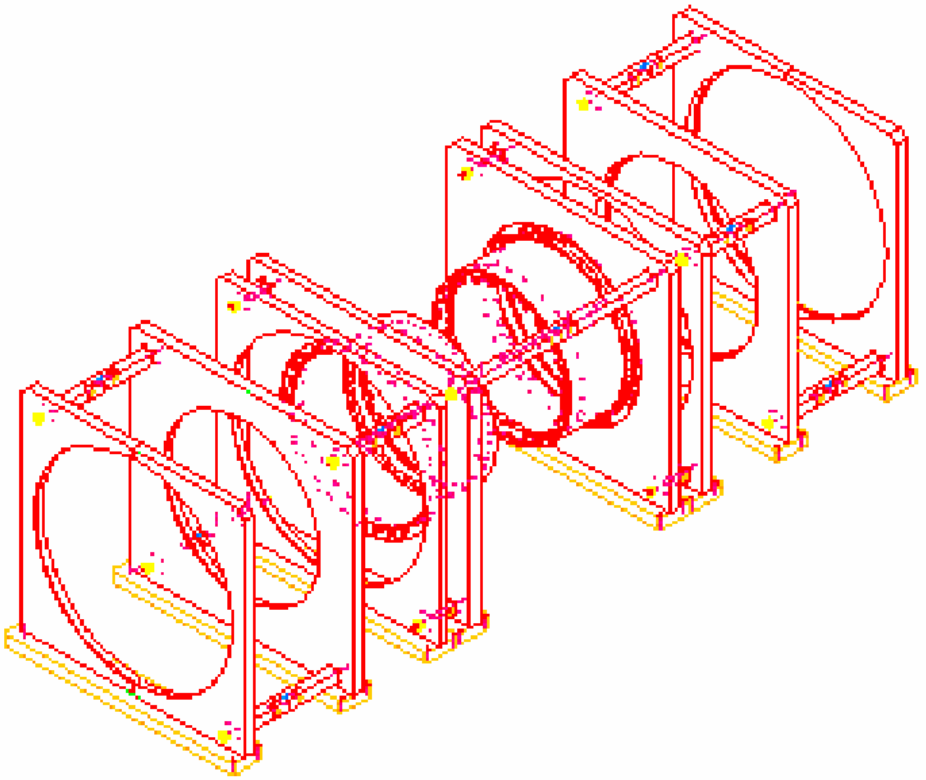


R-Φ side

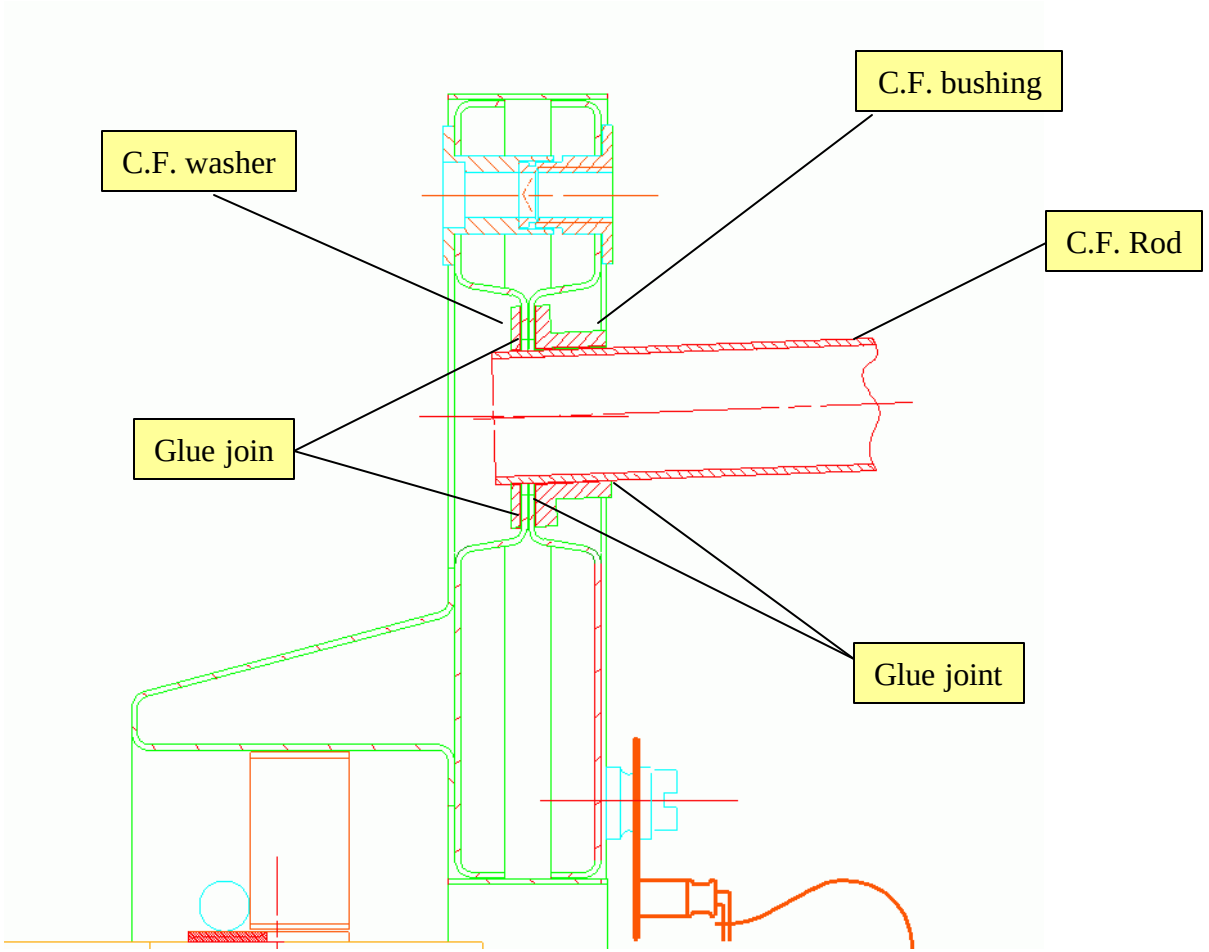
Wedge shape to max rigidity

Space Frame Assembly

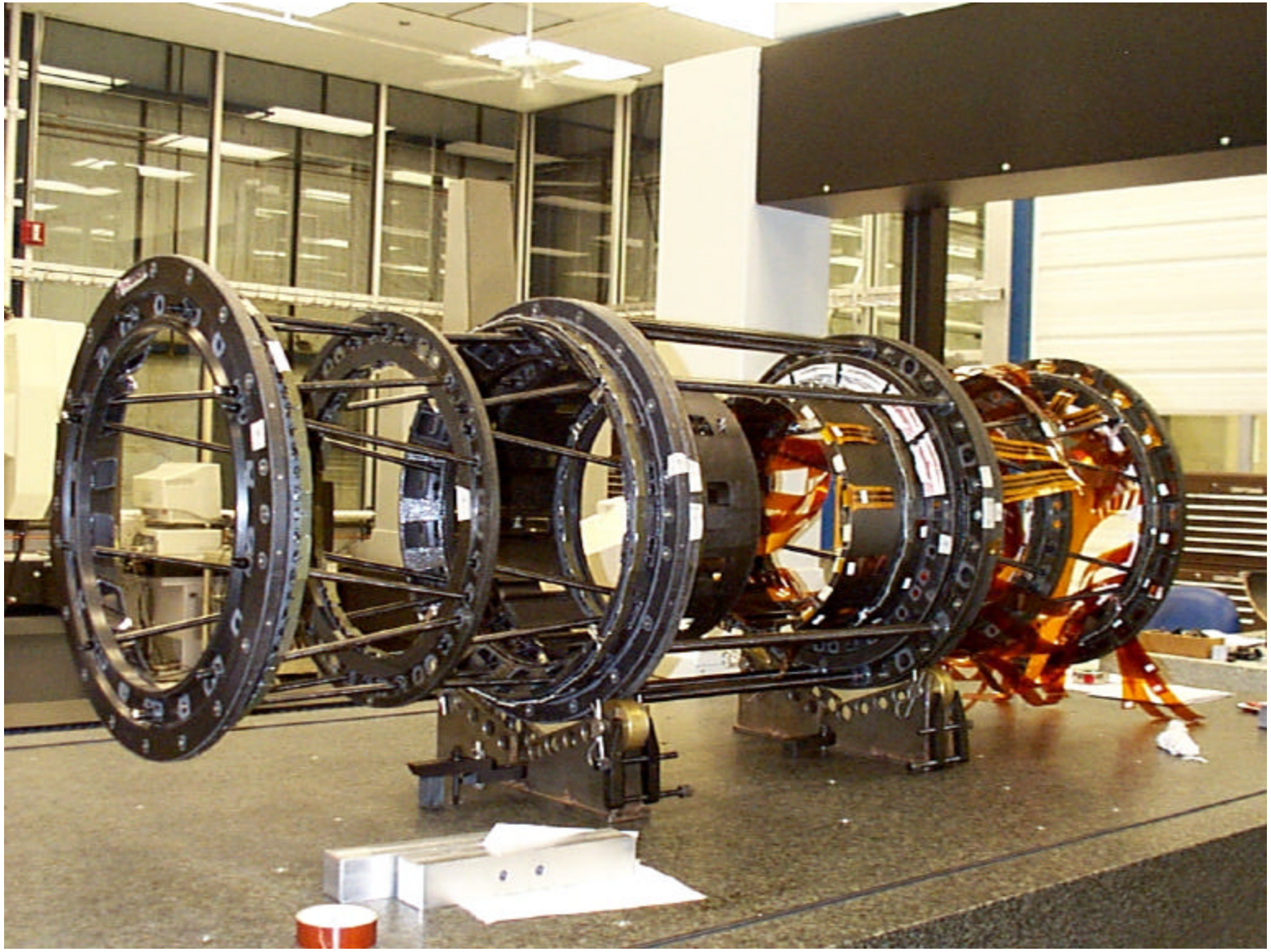
- Flanges held in place by fixtures accurately positioned relatively to one another
- Once the flanges are in place, rods have been attached via washer-bushing glue joints (see next slide)
- The space frame was assembled as a whole in Pisa, Italy, then disassembled into three sections and shipped to Fermilab



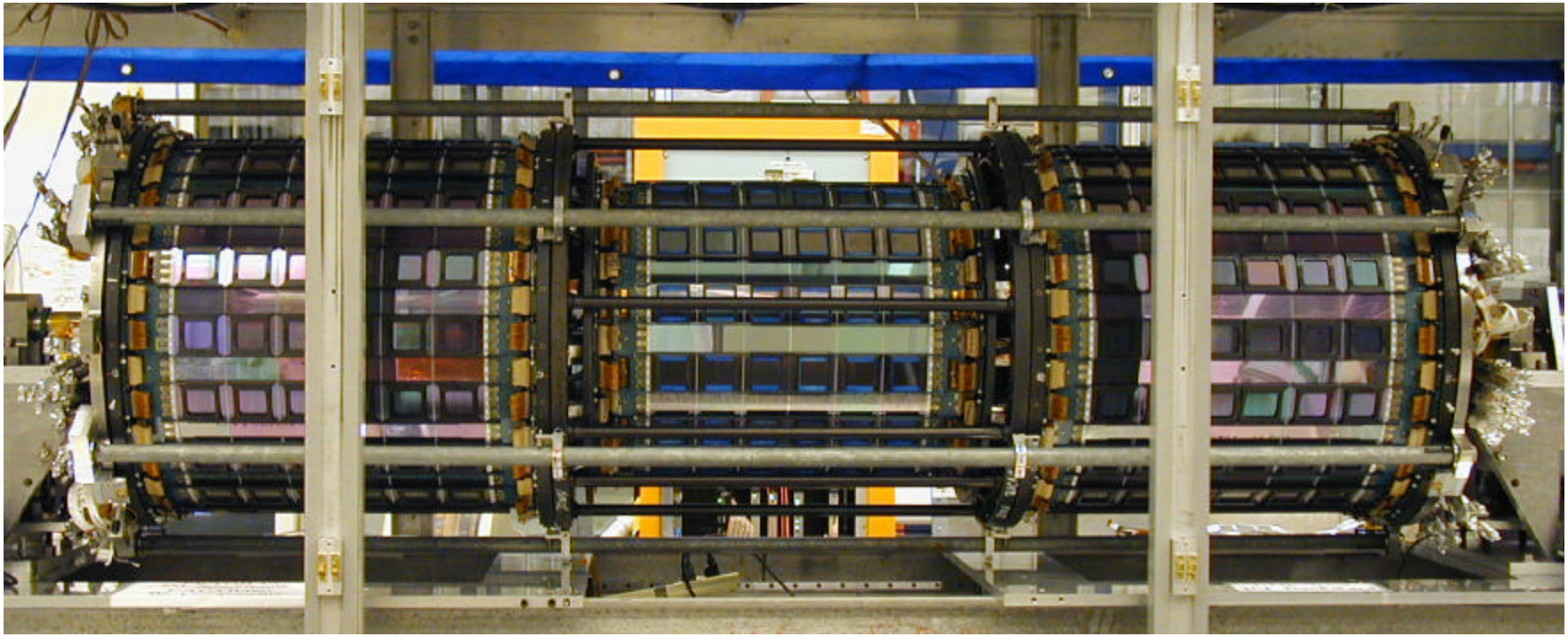
Rod-Flange Joint Detail



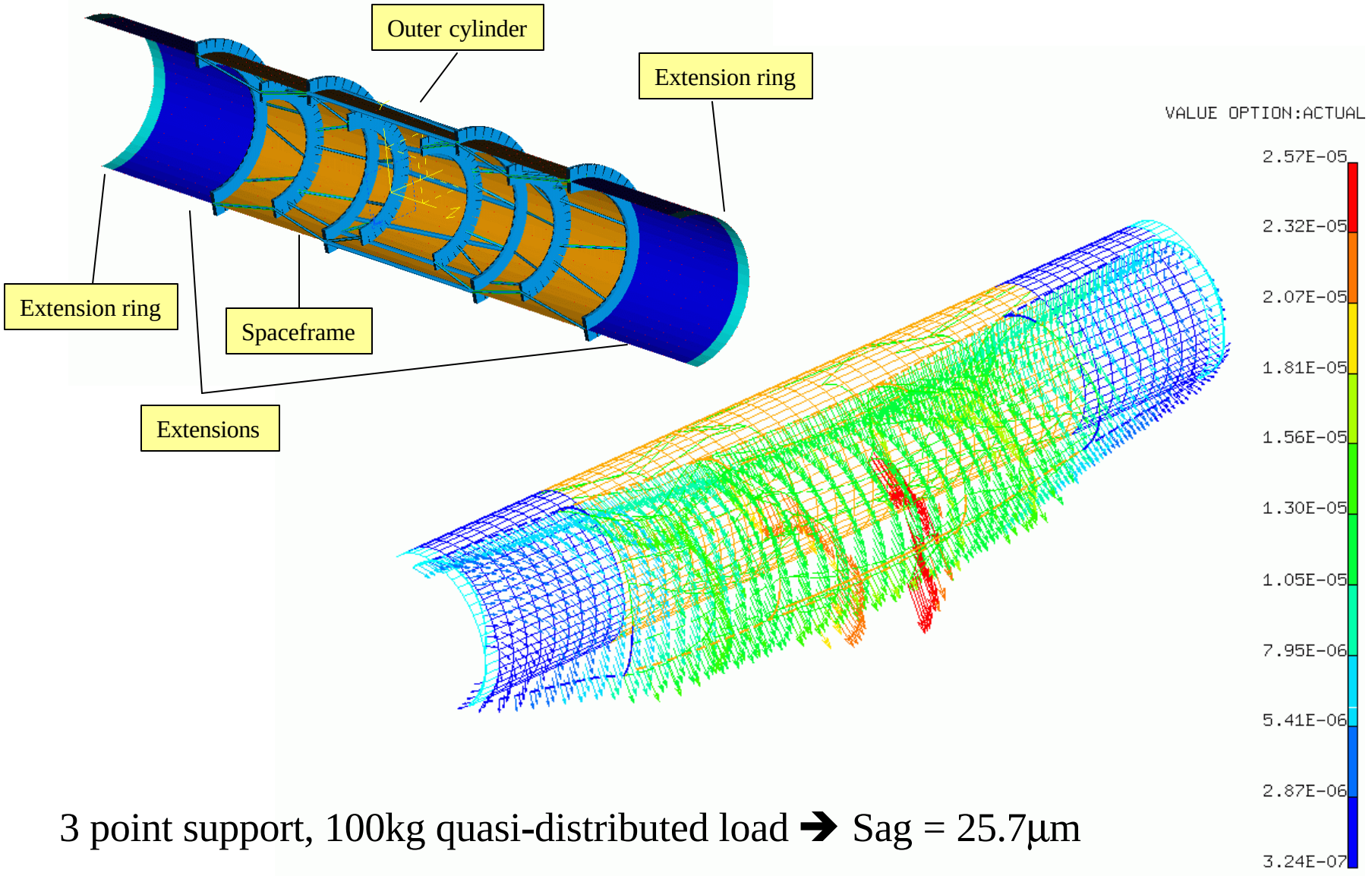
The ISL space frame “naked”…



… and the whole story



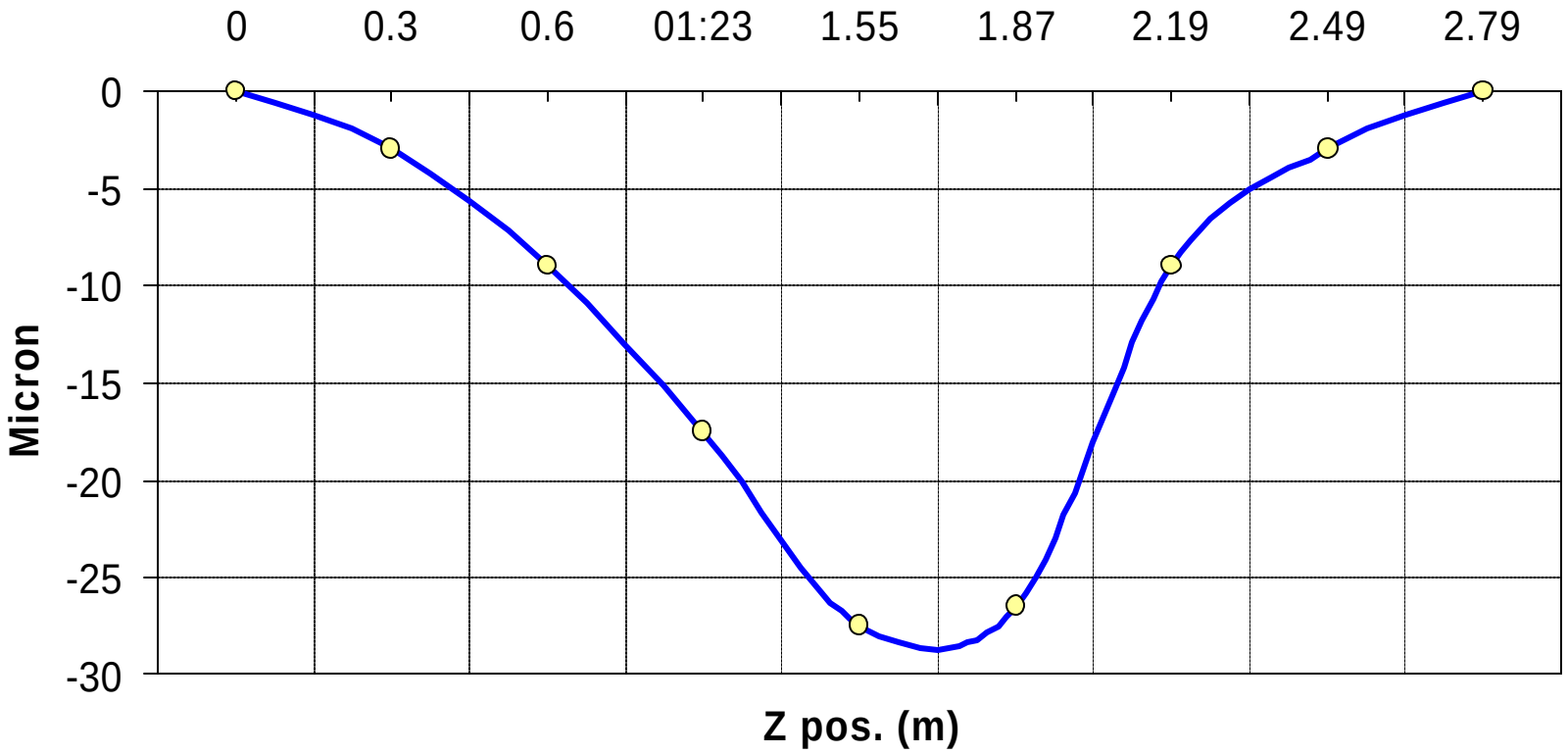
Space Frame Deflection FEA



3 point support, 100kg quasi-distributed load ➔ Sag = 25.7μm

Space Frame Deflection Test

- 3 points support
- Maximum deflection for 100kg quasi-distributed load <30µm
- Good agreement with FEA model (25.7 vs 29µm)



Some numbers…

- 888 large area, double sided silicon microstrip sensors.
- 512 strips on each side with a pitch of 112μm
- Strips on one side have a stereo angle of 1.2 degrees
- Sensors grouped into readout triplets (*modules*)
- Each module has double-sided AlN readout hybrid.
- Modules are paired to form the *ladder* (total 148 ladders)

ISL Heat Power Dissipation

Layer	# ladders	Total power (Watt)
6.C.	28	291.2
6.F.	24	249.6
6.B.	24	249.6
7.F.	36	374.4
7.B	36	374.4
Total ladders		148
Total power		1539.2

NOTE: This value does not include the heat generated by the port cards that are placed outside the ISL volume

Cooling Requirements

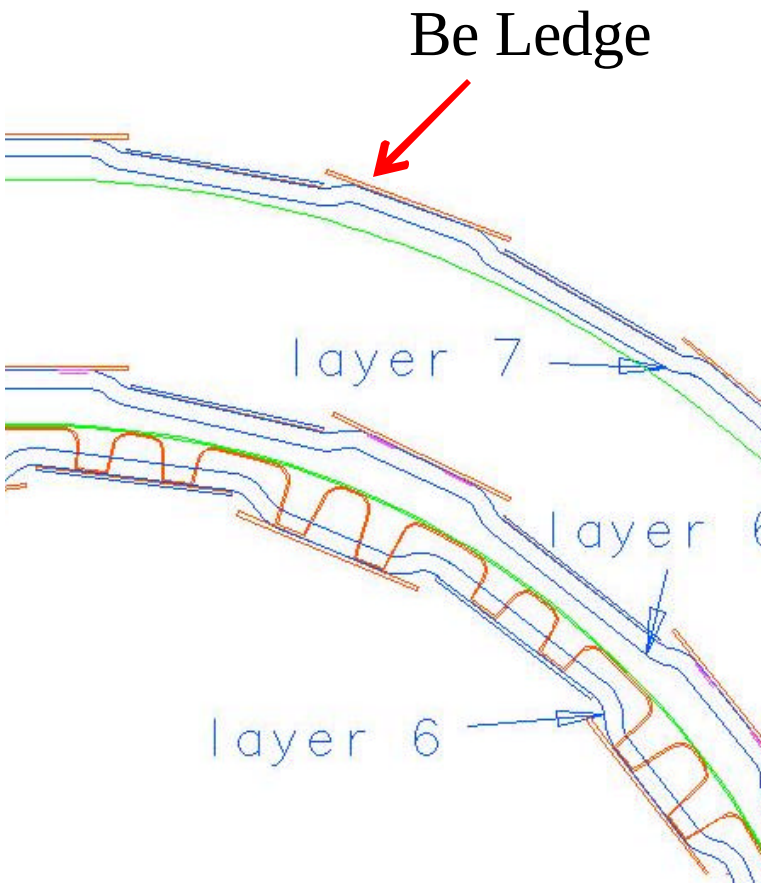
- Max silicon temperature < 25°C
- Max read out electronics temperature < 35°C
- Max. ΔT_{bulk} (inlet-outlet) ~1 °C (to avoid thermal stress)
- Pressure losses inside the spaceframe must be less of 0.06 MPa (~8.7psi)

30% Dowcal 10

Density	**Specific heat**	**Thermal conductivity**	**Viscosity**	**Freezing point**
[Kg/m^3]	[J/kg K]	[W/m K]	[Pa s]	[°C]
1052	3602	0.434	4.58×10^{-3}	-12.7

ISL Cooling System

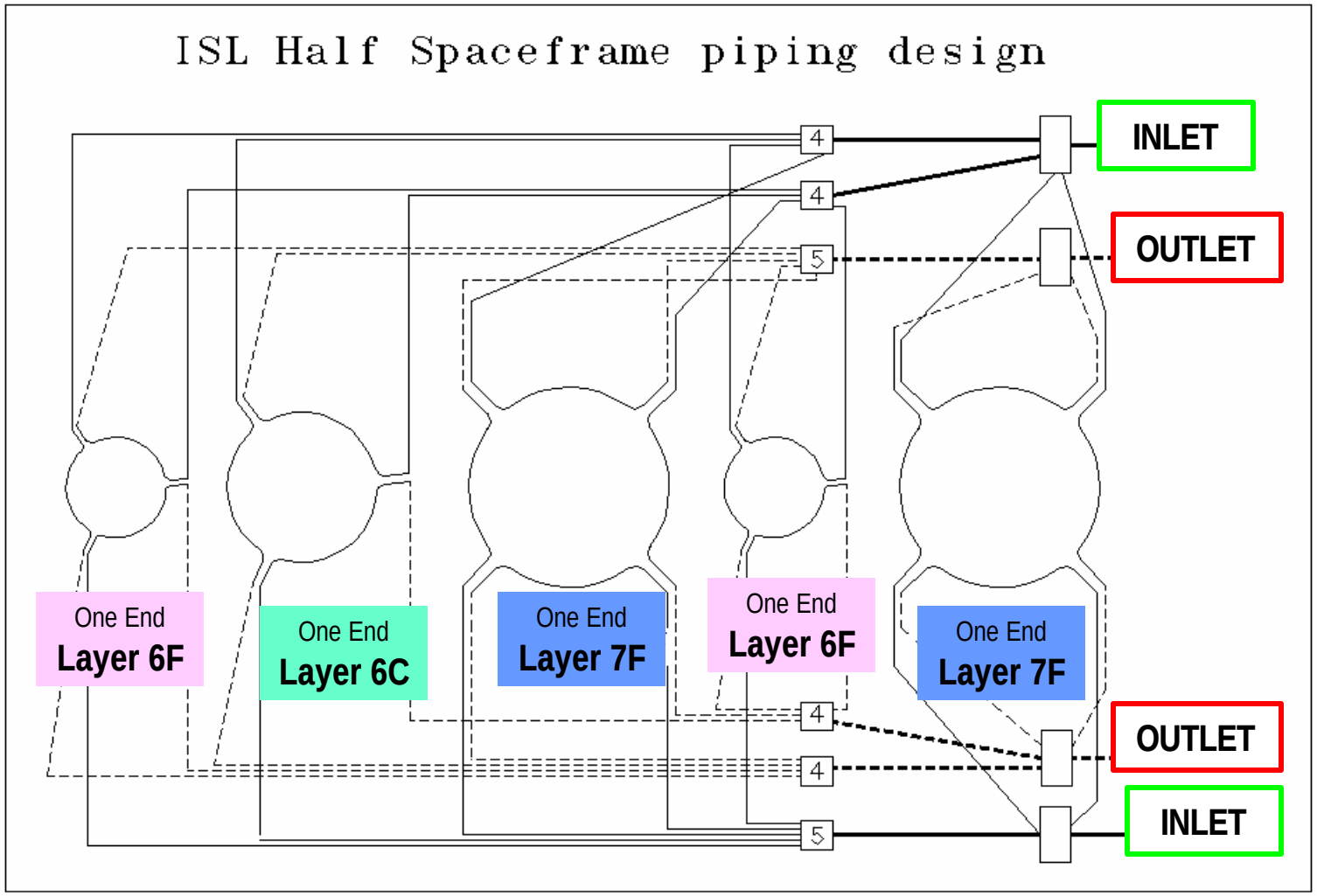
- The ISL module is refrigerated by a cold fluid flowing in aluminum pipes, which are joined to a **beryllium ledge** with thermally conductive glue.
- The module hybrid is kept in thermal contact with the cold ledge by means of a pressure generated by a screw. Using this method the module can be mounted and dismounted from the structure.
- Tube inner diameter 3.9mm



ISL Cooling System

- ISL volume is kept at 20 °C fluxing cold nitrogen
- The fluid circulation is arranged in layers.
- Pressure losses below 0.06MPa (~8.7psi), hence
  - 3 inlets/outlets for Layers 6F, 6B
  - 3 inlets/outlets for Layers 6C
  - 4 inlets/outlets for Layers 7F, 7B
- Two inlets and outlets at each ends of the spaceframe. Each of the two inlets is connected to a supply line from the chiller

The Cooling Circuit – ½ Space Frame



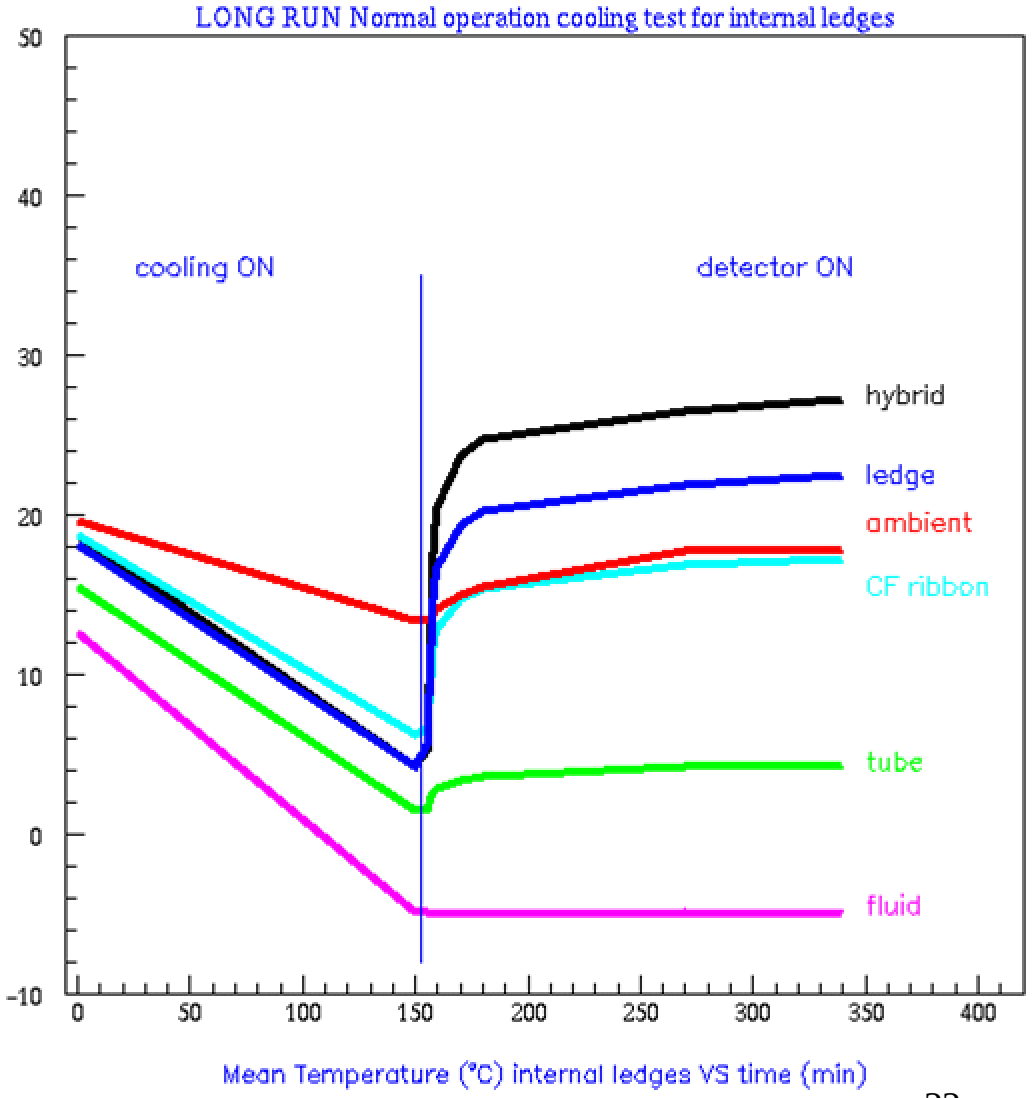
ISL Flow Budget

Layer	30% Dowcal 10 Flow	
	(Kg/s)	(liter/min)
6.C.	0.04042	2.30
6.F.	0.03464	1.98
6.B.	0.03464	1.98
7.F.	0.05197	2.96
7.B.	0.05197	2.96
Total	**0.2136**	**12.18**

ISL cooling test

TEST SETUP

- T_{bulk} = -5°C
- single detector test at 4 W for internal ledges
- Coolant: 40% glycol-ethylene
- detector on after the cooling



ISL Thermal Performance Summary

- For T_{bulk} = –5 °C ➔ T_{hybrid} ~ 30 °C
- At chip nominal power consumption (0.425 W), ΔT_{bulk}(inlet-outlet) ~0.6°C. It is ~1.3°C running at the maximum power consumption (0.625 W).
- The max sensor temperature is within specs (20 °C) even for the max power.

Conclusions

- The ISL Space Frame is an efficient structure that supports ISL and provides it the necessary cooling
- The max sag in the final configuration is ONLY 30μm
- $T_{SILICON} < 20°C$ (~1.5 KW) @ $T_{bulk} = -5\ °C$
- Max flow rate ~12 L/min